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MINERAL BOTTOM GEOMORPHIC INVESTIGATION TRIP REPORT

Prepared for

Colorado River Water Conservation District
P.O. Box 1120
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Prepared by

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RCE Ref. No. 91-714.01

December 1992

TRIP REPORT

LOCATION: Green River, Utah

DATES: May 12 to 14, 1992

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RCE Project No. 91-714-01.

SUBMITTED TO: Mr. Ray Tenney, P.E.
Colorado River Water Conservation District

DATE: December 3, 1992

INTRODUCTION

Between May 12 and 14, 1992, Drs. Mike Harvey and Bob Mussetter of Resource Consultants & Engineers, Inc. (RCE) in the company of individuals from the U.S. Fish and Wildlife Service (USFWS), the Colorado River Water Conservation District (CRWCD) and the U.S. Bureau of Reclamation (USBR) conducted a water-borne field inspection of the Green River from the Town of Green River, Utah at River Mile (RM) 120 to Unknown Bottoms at RM 28. During the field inspection the discharge of the Green River was about 9,500 cfs.

The primary objective of the trip was to provide an interdisciplinary overview of this reach of the Green River in terms of historical and present usage of habitat by threatened and endangered native species, especially the Colorado Squawfish. Specific areas of interest were: 1) the effects of Tamarisk (**Tamarix chinensis**) on channel morphology and capacity within the reach, 2) the effects of water storage projects on the frequency of overbank flows within the reach, and 3) the consequences of both areas of interest on potential within and out-of-channel (bottomlands) habitat utilization by larval and juvenile stages of the endangered and threatened species. Larval stages are distributed downstream from spawning sites by the mechanism of passive drift and therefore their dispersement into overbank habitats is dependent on a temporal concurrence of larval presence (a function of drift rate) and greater than bankfull discharge at a location where there is a floodplain of sufficient width to provide the low velocity, shallow flow conditions required by the larval stages.

TRIP OBSERVATIONS

1) Tamarisk

Graf's (1978) study of the effects of the invasion of tamarisk on the morphology of the Green River within Canyonlands National Park indicated that the establishment of dense stands of the plant along the riparian margins of the river had caused channel width to narrow by about 27 percent between 1915 and 1951. Establishment of the vegetation was probably assisted by a period of drought that lasted into the 1940s. Subsequent high flows in the 1950s did not appear to remove the tamarisk. In general terms, establishment of dense stands of riparian vegetation increases the hydraulic resistance so that overbank flows tend to deposit their sediment loads more rapidly thereby accelerating the process of natural levee formation. With an effective increase in the height of the bank as a result of natural levee formation, the channel capacity increases and the frequency of overbank flows is diminished. On the Green River, Graf (1978) concluded that prior to colonization of the channel margins by tamarisk, overbank flooding was infrequent and occurred only during the highest floods. He argued that channel constriction and reduced erodability of the banks due to tamarisk colonization increased the frequency of overbank flooding, such that flooding occurred even at modest discharges. Eventually, if the increased frequency of overbank flows caused natural levee formation, the frequency of overbank flows must have decreased through time.

banks. Mass failure of the banks also causes removal of the bank vegetation in what appears to be a self-regulating feedback mechanism. Since the undercutting of the banks (the mechanism that steepens the bank angle) occurs during relatively low flows, it can be argued that the increased duration of mid range flows following dam emplacement on the Green River (Andrews, 1986) has increased the rate at which the tamarisk is being removed.

2) Channel Capacity

Determination of the frequency of overbank flooding along the study reach of the Green River is dependent on being able to define the channel capacity. To achieve this, a number of cross sections were surveyed during the field inspection. At Cottonwood Bottom, the USFWS had established an IFIM site in 1980 with the additional purpose of having a channel monitoring site to investigate aggradation/degradation trends in this reach of the river. Six cross sections were surveyed, tied together horizontally and vertically and monumented, between RM 55 and RM 56. The cross sections were surveyed at discharges of 10,000, 5,100 and 2,600 cfs. The plotted cross sections (provided by Mr. George Smith, USFWS) clearly indicate that cross section geometry is dependent on discharge (Harvey and Watson, 1989; Anthony and Harvey, 1992) and that aggradation/degradation trends should be based only on resurveys conducted at similar discharges. Cross sections (transects) 2, 3, 4, and 6 were relocated and resurveyed on 14 May, 1992 at a discharge of about 9,500 cfs. The plotted cross sections are attached to this report (Appendix A). Also shown on the plotted cross sections are the profiles for the 10,000 cfs survey in 1980. Comparisons of the profiles indicates that there has been very little change at any of the cross sections other than what is to be expected given the minor differences in discharge between the 2 surveys.

Cross sections were also surveyed at 8 locations at Unknown Bottom between RM 28.5 and RM 31.3. The subaqueous portions of the cross sections were recorded on a fathometer trace and later digitized. Observations of the bank heights and inclinations were made as well and the surveyed bank profiles for the Cottonwood Bottom cross sections were transferred to the appropriate cross sections (on the basis of location within the bend) at the downstream location. Cross section stationing, and hence the horizontal relationship between the sections was approximated from the topographic map. (The channel slope was also approximated from the topographic maps at the Unknown Bottom location.) The plotted cross sections are attached to this report (Appendix B).

The surveyed cross sections at the two locations were used to create HEC-2 models for each of the reaches. At the Cottonwood Bottom reach, the bankfull discharge for the individual cross sections ranged from 34,000 to 22,000 cfs for a Manning's n value of 0.03 and from 29,000 to 19,300 cfs for an n value of 0.035. Average values for the reach were 32,980 and 28,167 cfs for n values of 0.03 and 0.035, respectively. At the Unknown Bottom reach the bankfull discharge for the individual cross sections ranged from 41,900 to 34,000 cfs for an n value of 0.03, and 41,900 to 30,200 cfs for an n value of 0.035. Average values for the reach were 36,240 and 32,560 cfs for n values of 0.03 and 0.035, respectively.

To determine the frequency of inundation of the bottomlands, a flow duration curve was developed from mean daily flows for the Green River at the Green River, Utah gaging station for the period 1963 to 1990 (**Figure 1**). Also shown on the figure is the flow duration curve for the period between 1963 and 1982 developed by Andrews (1986). Comparison of the curves demonstrates the effects of the high discharge years of 1983, 1984 and 1986 on the upper end of the flow duration curves. At the Cottonwood Bottom reach, the exceedence frequencies for the reach averaged bankfull discharges are 1.3 percent and 0.8 percent for n values of 0.03 and 0.035, respectively. The exceedence frequencies translate into 4.7 and 2.9 days per year. At the Unknown Bottom reach the exceedence frequencies for the reach average bankfull discharges are 0.4 percent and 0.3 percent for n values of 0.03 and 0.035, respectively. The exceedence frequencies translate into 1.5 and 1.1 days per year. The exceedence frequencies represent average values and they do not indicate that bankfull discharge is exceeded every year. In fact, as the next paragraph shows, bankfull discharge at the 2 sites has a return period of between 4 and 10 years.

Graf's interpretation of the effects of tamarisk colonization on the frequency of overbank flooding does not take into account the substantial modification of cross section geometry that occurs in sand bed streams under high flow conditions, when the channel banks are relatively erosion resistant (Anthony and Harvey, 1991). Evidence of cross section adjustments occurring on the Green River with changes in discharge is provided by the repeat cross section surveys at the Cottonwood Bottom IFIM site.

If Graf's (1978) interpretation of the effects of tamarisk colonization are correct then it appears that under natural pre-dam and pre-tamarisk conditions there was very little **overbank** larval stage habitat along the lower Green River. This suggests that Razorback sucker larvae that were hatched just before or near the peak of the annual hydrograph (Tyus and Karp, 1989) and drifted downstream to this reach of the river would have been flushed on downstream. It should be recognized that this reach of the Green River is a bedrock-constrained reach and that there was never a wide alluvial floodplain even prior to the introduction of tamarisk. From the point of view of the Colorado Squawfish larvae the frequency of overbank flooding is moot because the squawfish spawn on the recessional limb of the hydrograph (Tyus and Karp, 1989), and therefore, under natural conditions they could not have utilized out-of-bank habitat. The reduced channel width may have an effect on the squawfish larvae if the low flow habitat has been significantly affected.

Our observations of the distribution of riparian vegetation along the Green River from RM 120 to RM 28 (confluence with the Colorado River is RM 0) are somewhat at variance with those of Graf (1978). There appears to be a range of conditions along the reach. In some locations dense stands of willows of substantial age and size comprise the riparian vegetation. At other locations the riparian vegetation is comprised of both tamarisk and willows, and at yet other locations the vegetation is comprised exclusively of tamarisk. Given the amount of time available to observe these variations in species composition, we were unable to determine any associations between specific geomorphic factors and species distribution.

Given the extensive presence of willows and to a lesser extent cottonwoods, in a wide range of geomorphic settings along the Green River, it is not immediately obvious why the common explanation for the persistence of tamarisk over willows was generated. It has been suggested that tamarisk persists during floods because flows are incapable of eroding the root-reinforced banks. Since willows are also riparian species whose roots reinforce banks (Gray and Ohashi, 1983; Smith, 1976), and willows have obviously reinforced banks and persisted along the Green River, it is not clear why Graf (1978) and others (Hadley, 1961) have suggested that before the advent of tamarisk the native riparian vegetation was removed by floods and therefore had little lasting geomorphic effect on the channels. Perhaps the depth of rooting or root density is greater for tamarisk than willow.

During the course of the field inspection of the Green River, it was observed that tamarisk was being removed by 2 different mechanisms. At Unknown Bottom a large area of tamarisk had died as a result of ponding of flows in the overbank area, probably in 1986. The depression on the left overbank area was the infilled remains of a cutoff channel segment. The cutoff at Bonita Bend (RM 31) had already occurred when Powell traversed this reach of the Green River in 1869. Flows entered the depression through a crevasse in the natural levee at about RM 30.6L and were prevented from spilling back to the river by the well developed and tamarisk vegetated natural levee. Given the relatively infrequent occurrence of overbank flows (see next section for a fuller discussion), it is unlikely that this mechanism for removing tamarisk is very effective.

Tamarisk was also being removed by lateral erosion of banks upon which it had become established. Stands of very large tamarisks on the outsides of bends, or where the channel was very deep, were being undercut by flows even though their roots extended to the water line. Vertical accretion as a result of vegetation-induced overbank sedimentation leads to increased bank height. In moderately cohesive upper bank sediments, bank stability is related to both bank angle and bank height, and therefore when bank angle is increased by fluvial erosion of the less cohesive bank toe sediments, the increased bank height caused by the vegetation-induced sedimentation leads to mass failure of the

Figure 2 shows the peak flow frequency curves (best fit and 95 percent confidence interval) for the period from 1963 to 1990 at the Green River gage. Depending on the n value used (0.03 or 0.035) at the Cottonwood Bottom reach, the bankfull discharge has a frequency of 25 to 28 percent which are equivalent to return periods of between 4 and 5 years. At Unknown Bottom, depending on the n value used (0.03 or 0.035), the bankfull discharge has a frequency of 14 to 20 percent which are equivalent to return periods of between 5 and 10 years. In contrast, **Figure 3** shows the peak flow frequency curves (best fit line and 95 percent confidence interval) for the period from 1894 to 1962. Depending on the n value used (0.03 or 0.035) at the Cottonwood Bottom reach, the bankfull discharge has a frequency of 50 to 58 percent which are equivalent to a return period of about 2 years. At Unknown Bottom the bankfull discharges have frequencies from 36 to 50 percent which are equivalent to return periods of 2 to 3 years.

The frequency and return period data obviously do not make any allowance for channel morphologic changes that may have been caused by the establishment of tamarisk (Graf, 1978). If in fact Graf's interpretation is correct, the frequency of overbank flows would have been lower prior to the advent of tamarisk.

3) Habitat Utilization Potential

Historical fish catch data indicate that juvenile Colorado Squawfish are abundant in the lower Green River (G, Smith, USFWS Memo. to Channel Monitoring Crew, 1992) which tends to suggest that there is adequate juvenile habitat in the reach.

Since the Colorado squawfish spawn on the recessional limb of the annual hydrograph (Tyus and Karp, 1989), and the larvae are distributed downstream by drift it is possible that the modification of the flow duration curve (see Andrews, 1986) has had an impact on the larval drift distance. Squawfish are known to spawn in canyon-bound reaches of the lower Yampa River (Tyus and Karp, 1989) and in Desolation Canyon (E. Wick, pers. communication) on the Green River. If the timing of larval emergence coincides with the longer duration mid-range flows, the larvae could in fact be carried farther downstream than would have occurred prior to flow regulation. With a narrower channel, the flow depth for a range of discharges following larval emergence will be higher and it is therefore conceivable that there will be less slackwater habitat for the larvae. Because of the magnitude of the bankfull capacity and the fact that squawfish spawn after the peak discharge, out-of-bank habitat will rarely, if ever, be available to larval squawfish in the lower Green River. Increased post-emergence releases from Flaming Gorge reservoir will tend to be counterproductive with respect to the larval stage of the squawfish.

The Razorback sucker spawns on the rising limb of the annual hydrograph (Tyus and Karp, 1989) and appears to have a fairly limited number of spawning locations on the upper Green River and the lower Yampa River (Tyus and Karp, 1990). Larvae are also dispersed by a drift mechanism, but if flows following larval emergence exceed bankfull there is a potential for them to utilize the out-of-bank habitat. In the reach of the Green River that is the subject of this report (RM 120 to RM 28) the frequency of exceedence of the bankfull discharge is low. If it is assumed that the bankfull capacity estimates for Cottonwood Bottom and Unknown Bottom are reasonably representative for the bottomlands downstream of RM 97 (confluence with San Rafael River) then it is also reasonable to conclude that in most years any Razorback sucker larvae that enter the reach will be passed through the reach. If flow releases from Flaming Gorge reservoir fail to increase the total discharge in the river to the point where the bankfull discharge is exceeded for whatever period is required for successful overbank habitat utilization, the increased flows will merely increase the larval drift rate and distance.

4) Recommendations

1. The channel capacity data at both Cottonwood and Unknown Bottoms and the flow duration and flood frequency data indicate that the lower reaches of the Green River are unlikely to be of great significance in terms of Razorback Sucker larval-stage habitat. Therefore, there does not appear to be much value in future channel capacity - overbank flow monitoring.

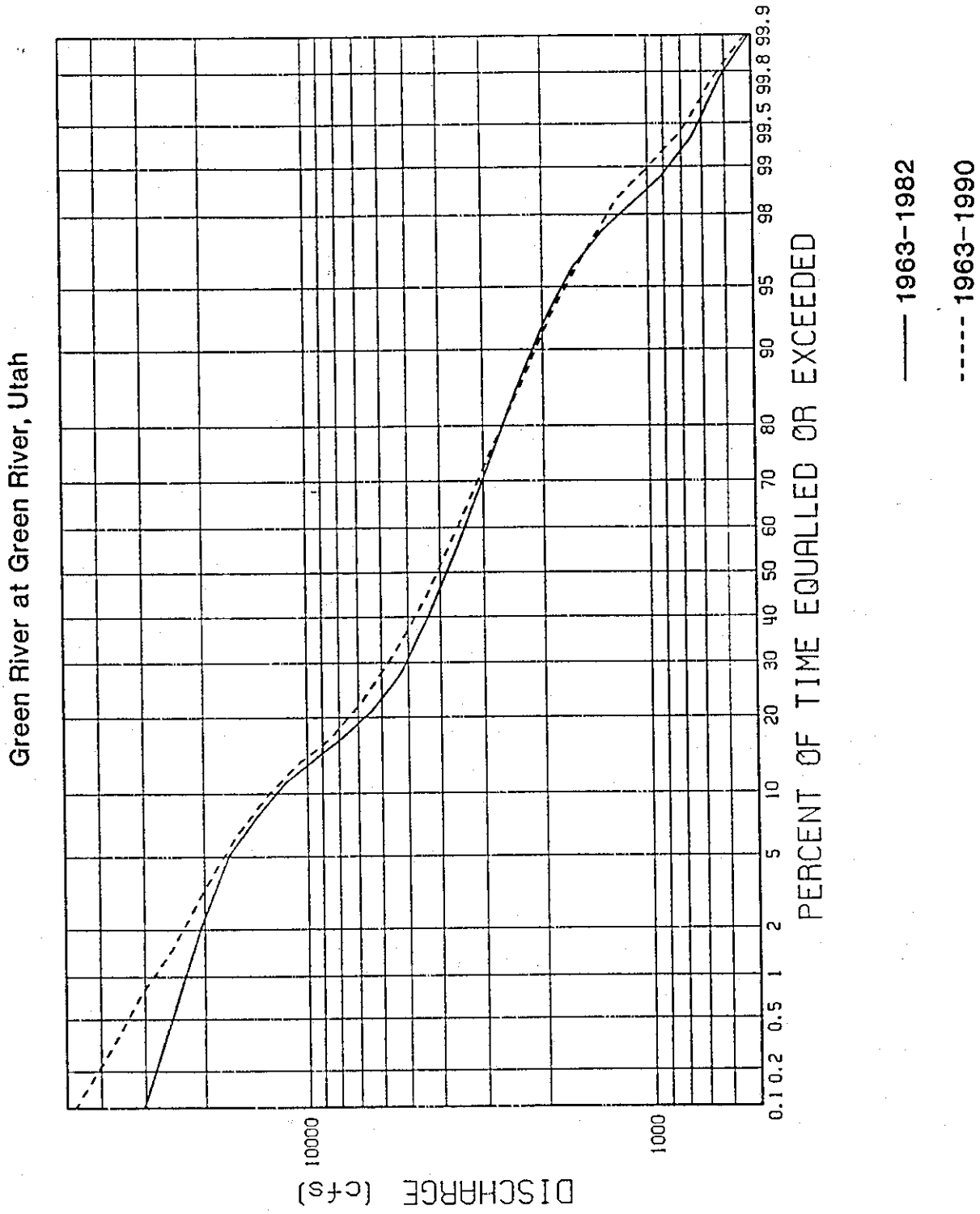

Figure 1. Flow duration curve for Green River at Green River, Utah, 1963-1990.

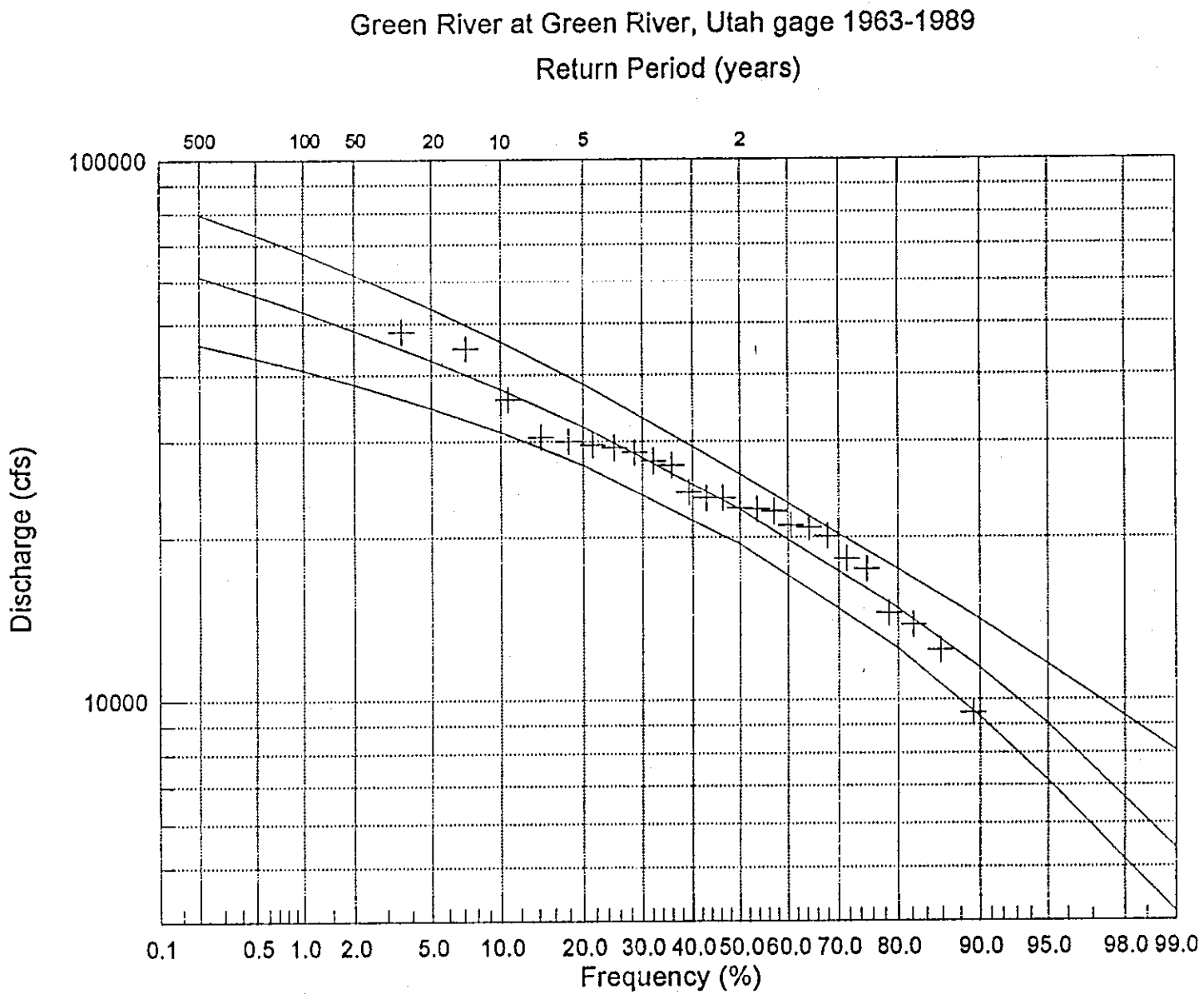

Figure 2. Peak flow frequency curves for Green River, at Green River, Utah, 1963-1990. Best fit and 95 percent confidence limits are shown.

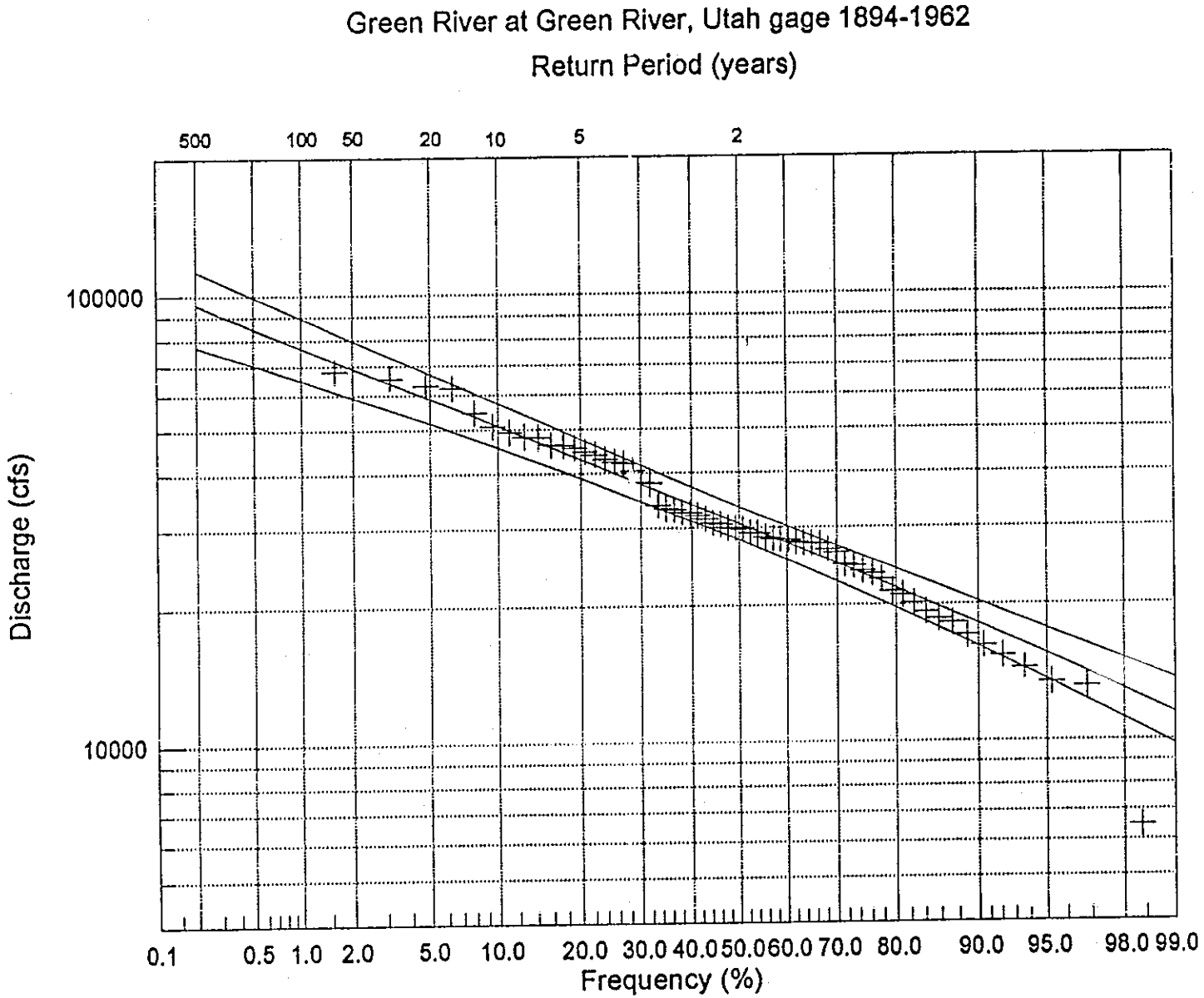

Figure 3. Peak flow frequency curves for Green River, at Green River, Utah, 1894-1962. Best fit and 95 percent confidence limits are shown.

2. Juvenile Colorado Squawfish appear to have satisfactory habitat in the lower reaches of the Green River. A field-based joint biological-geomorphic study of juvenile-stage habitat under low-flow conditions appears to be warranted. The joint study would aim to tie the physical dynamics and characteristics of the low-flow channel to juvenile-stage utilization, thereby providing a quantitative basis for habitat identification.

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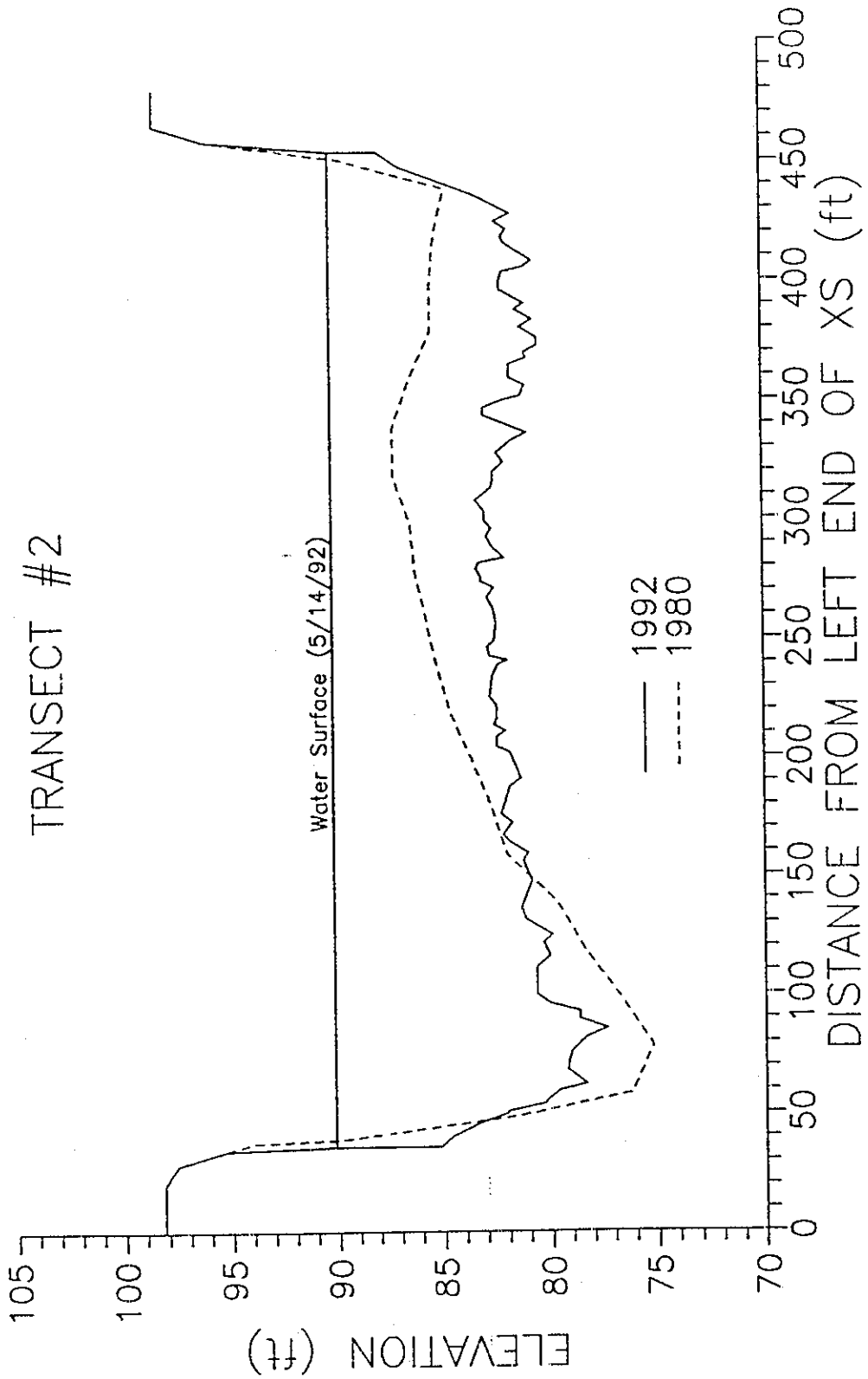
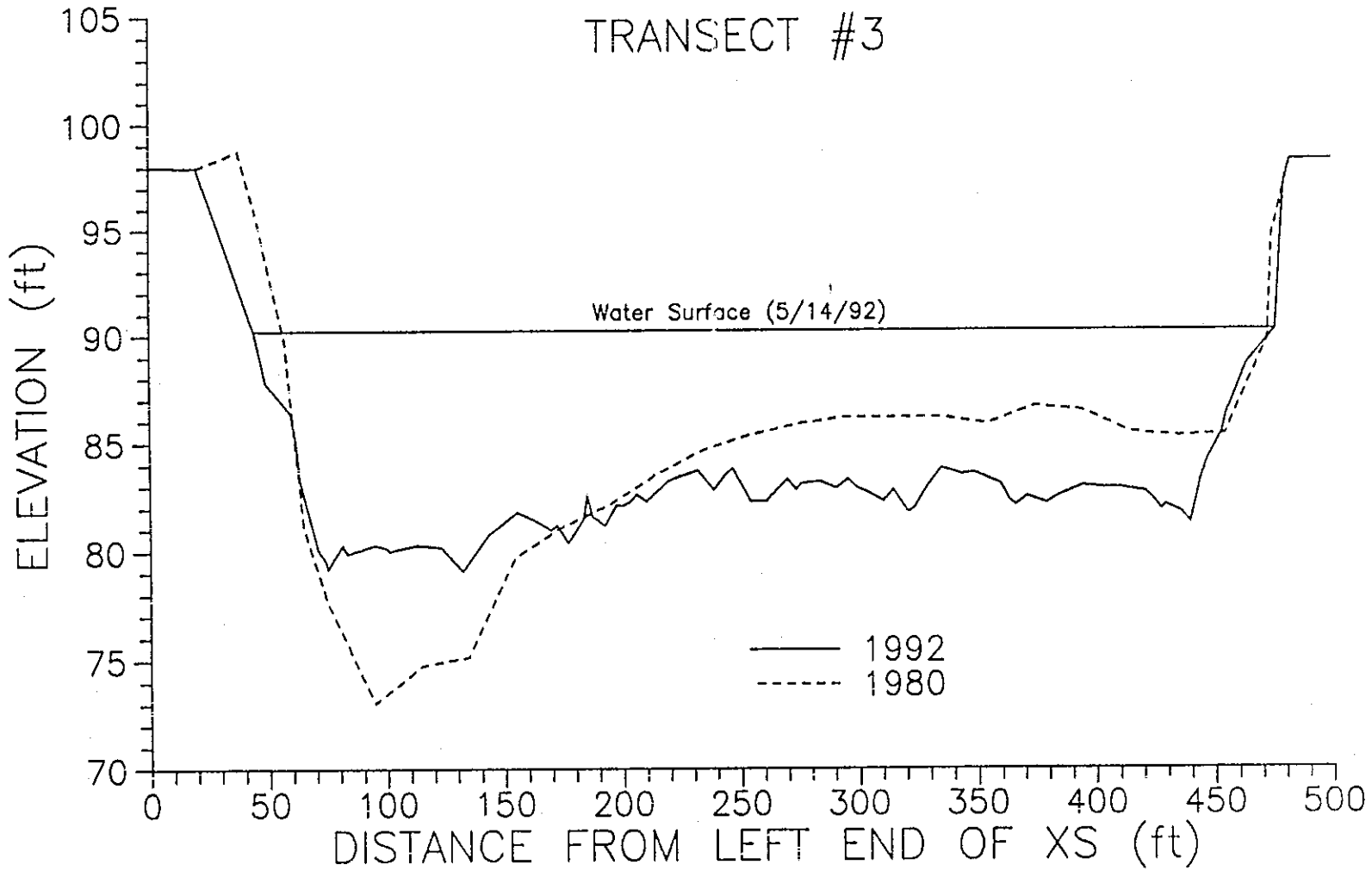
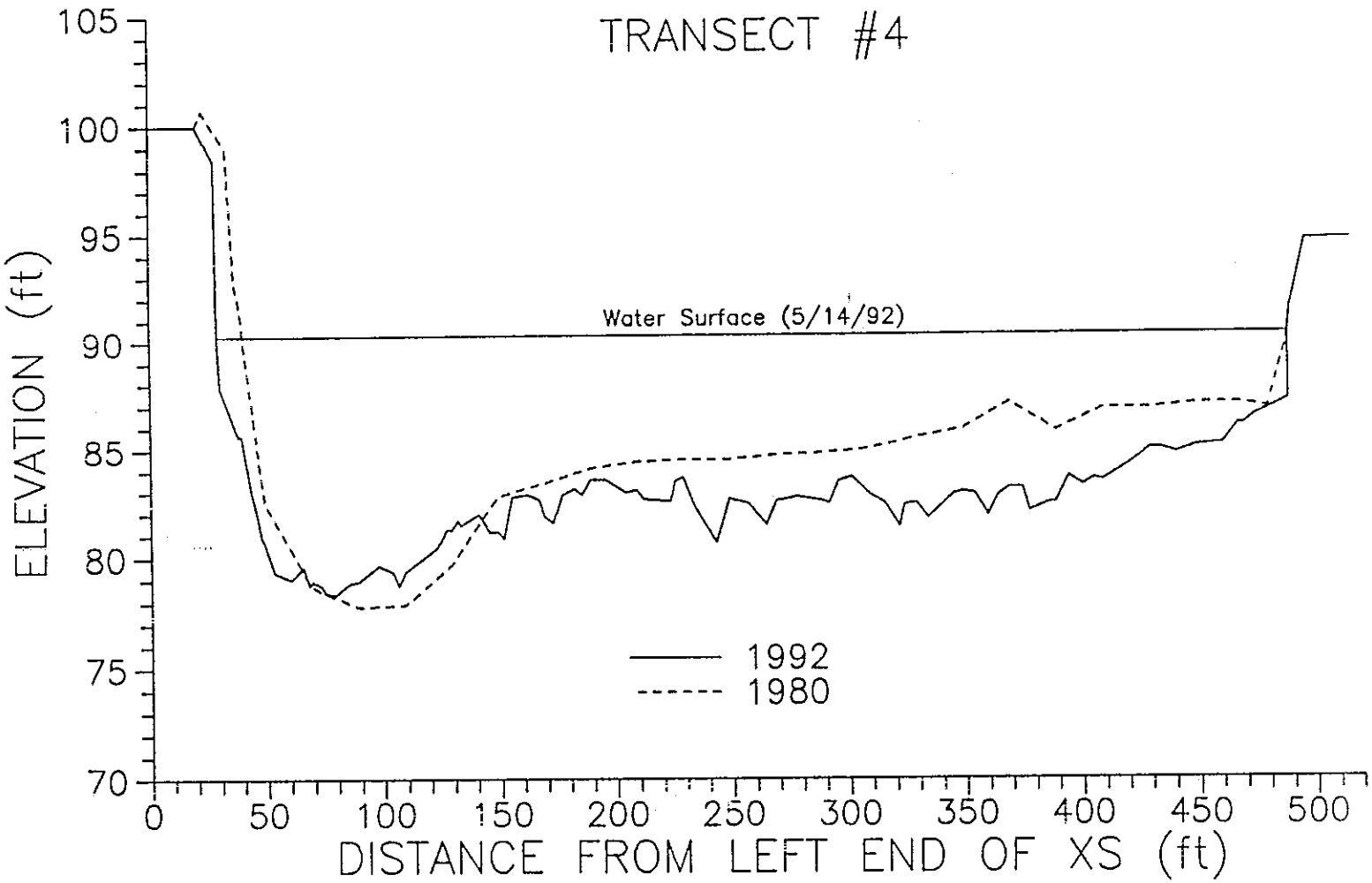
APPENDIX A

Cottonwood Bottom Cross Sections

All cross sections are plotted with the left bank (looking downstream) as the zero station.


TRANSECT #2
Water Surface (5/14/92)
1992
1980
ELEVATION (ft)
DISTANCE FROM LEFT END OF XS (ft)
105
100
95
90
85
80
75
70
0
50
100
150
200
250
300
350
400
450
500


TRANSECT #3
ELEVATION (ft)
105
100
95
90
85
80
75
70
Water Surface (5/14/92)
1992
1980
0
50
100
150
200
250
300
350
400
450
500
DISTANCE FROM LEFT END OF XS (ft)



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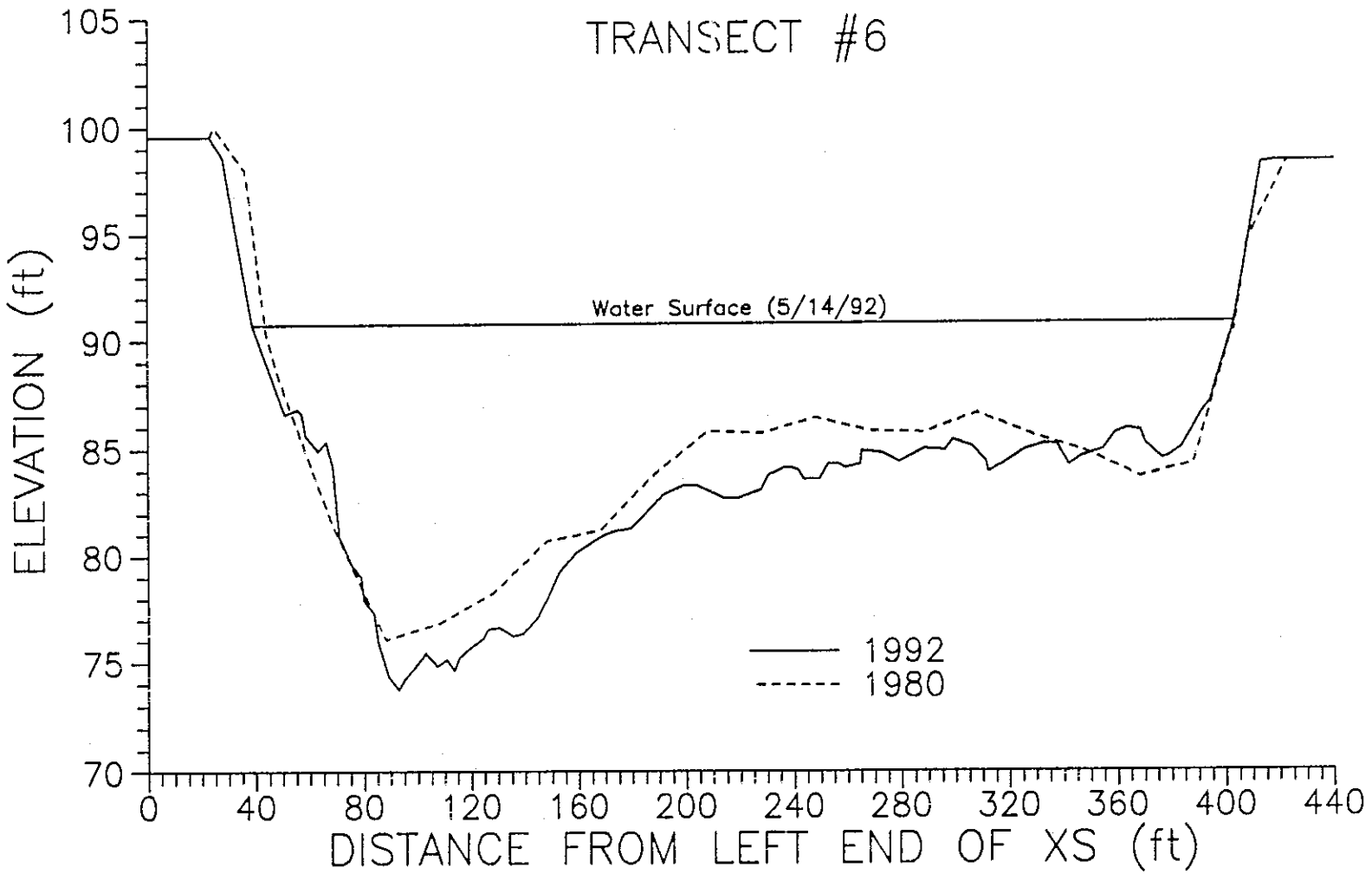

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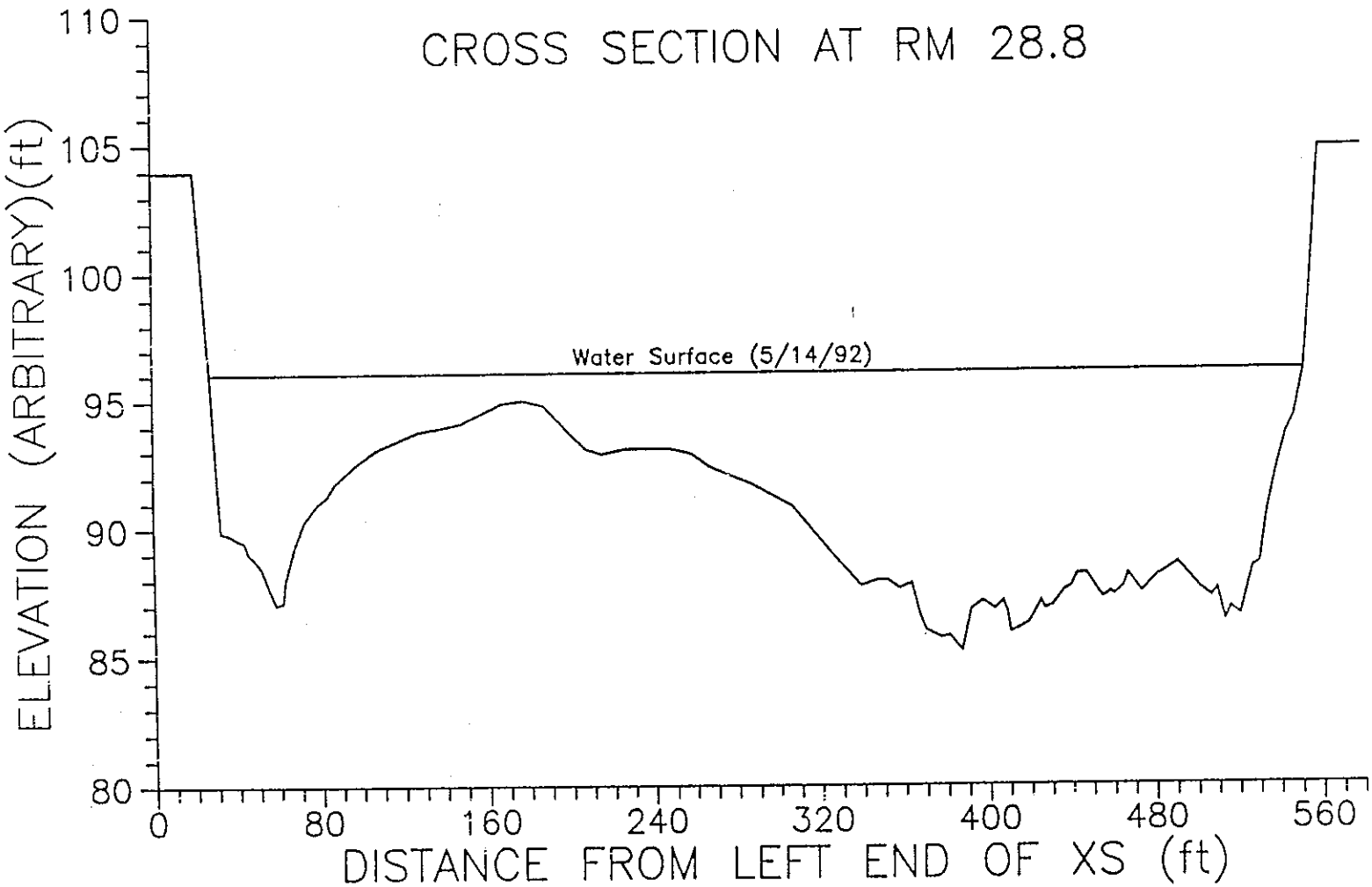
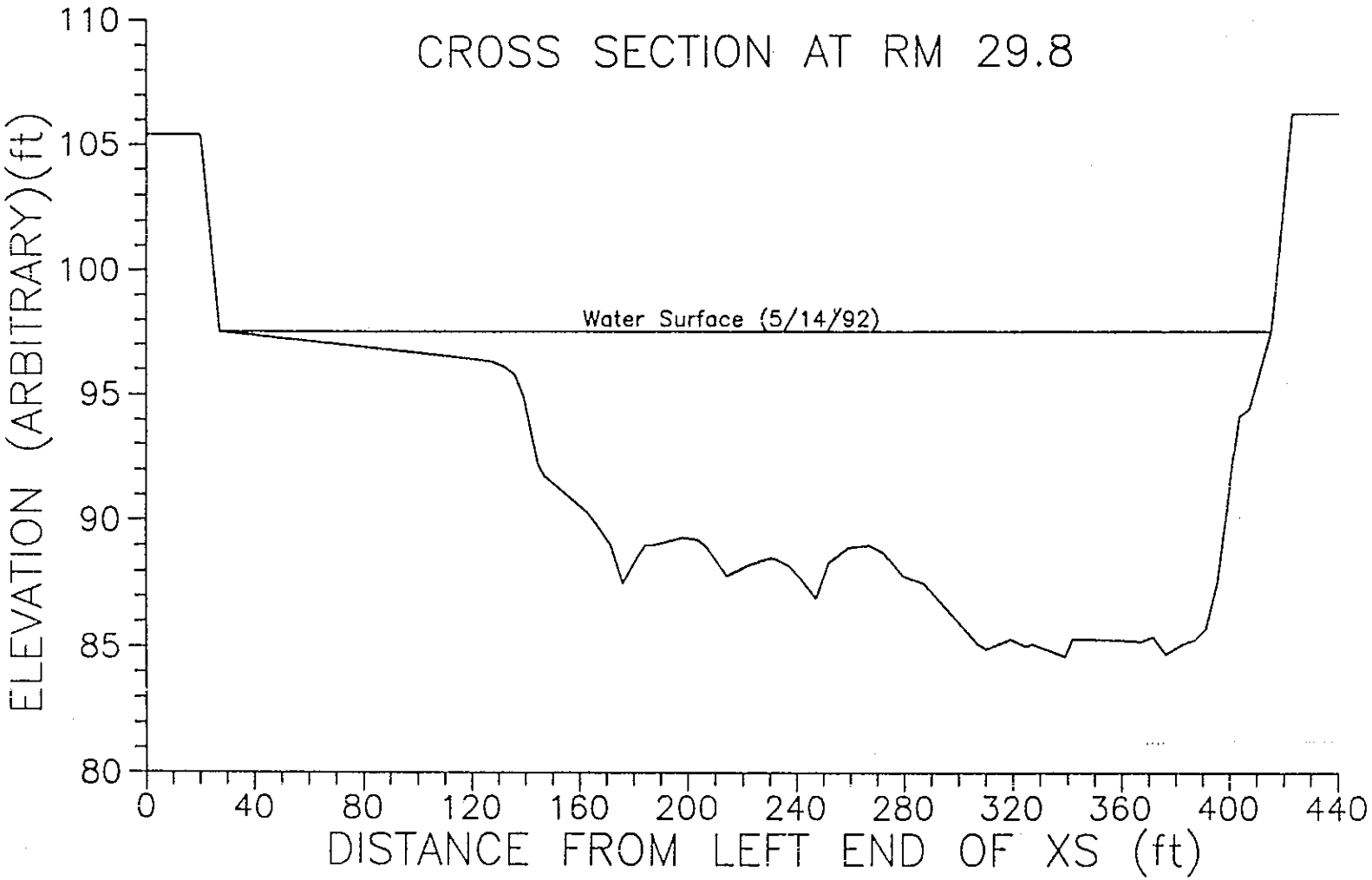
APPENDIX B

Unknown Bottom Cross Sections

All Cross sections are plotted with the left bank (looking downstream) as the zero station.


CROSS SECTION AT RM 28.8
ELEVATION (ARBITRARY)(ft)
110
105
100
95
90
85
80
Water Surface (5/14/92)
0
80
160
240
320
400
480
560
DISTANCE FROM LEFT END OF XS (ft)



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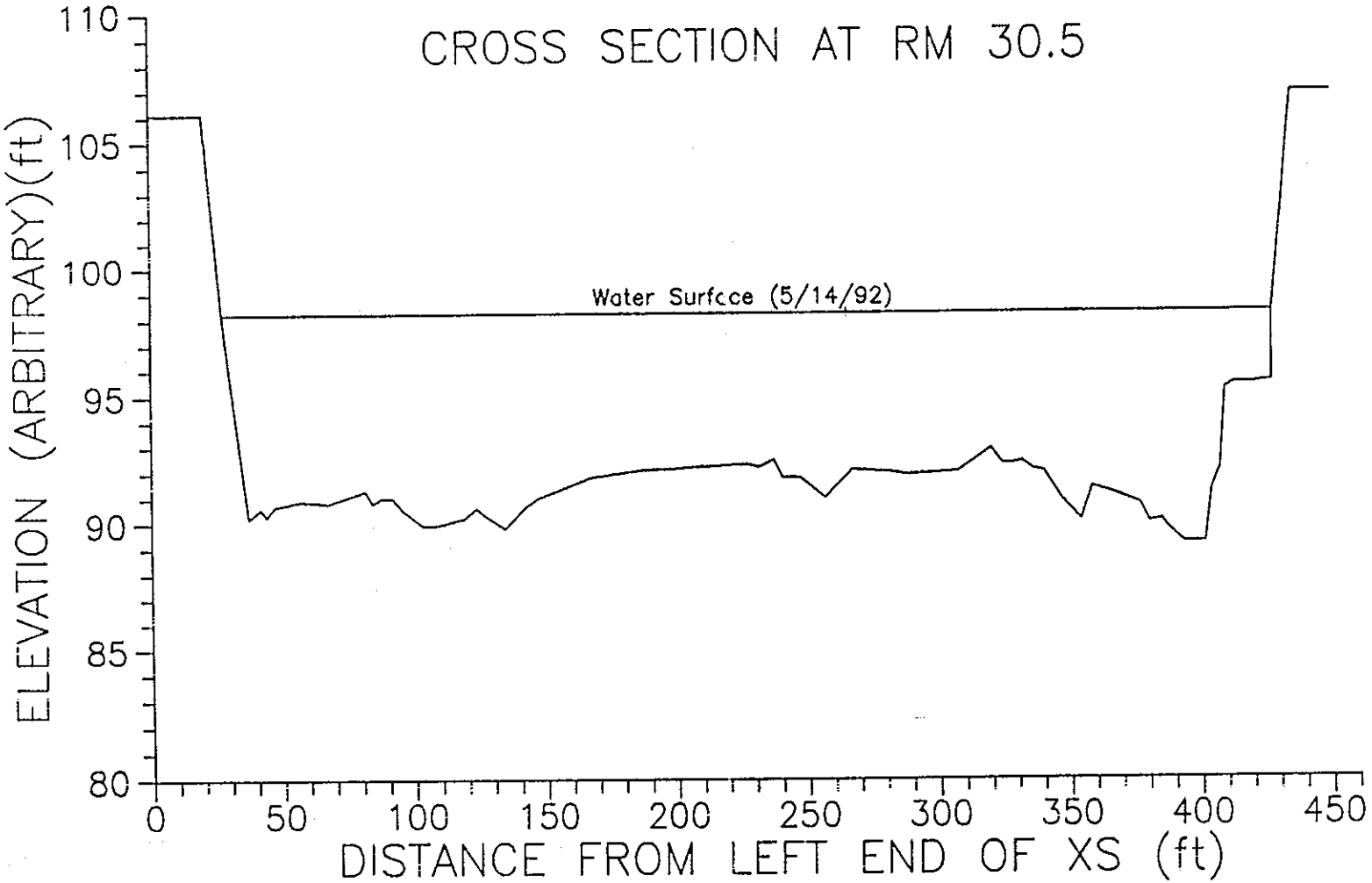

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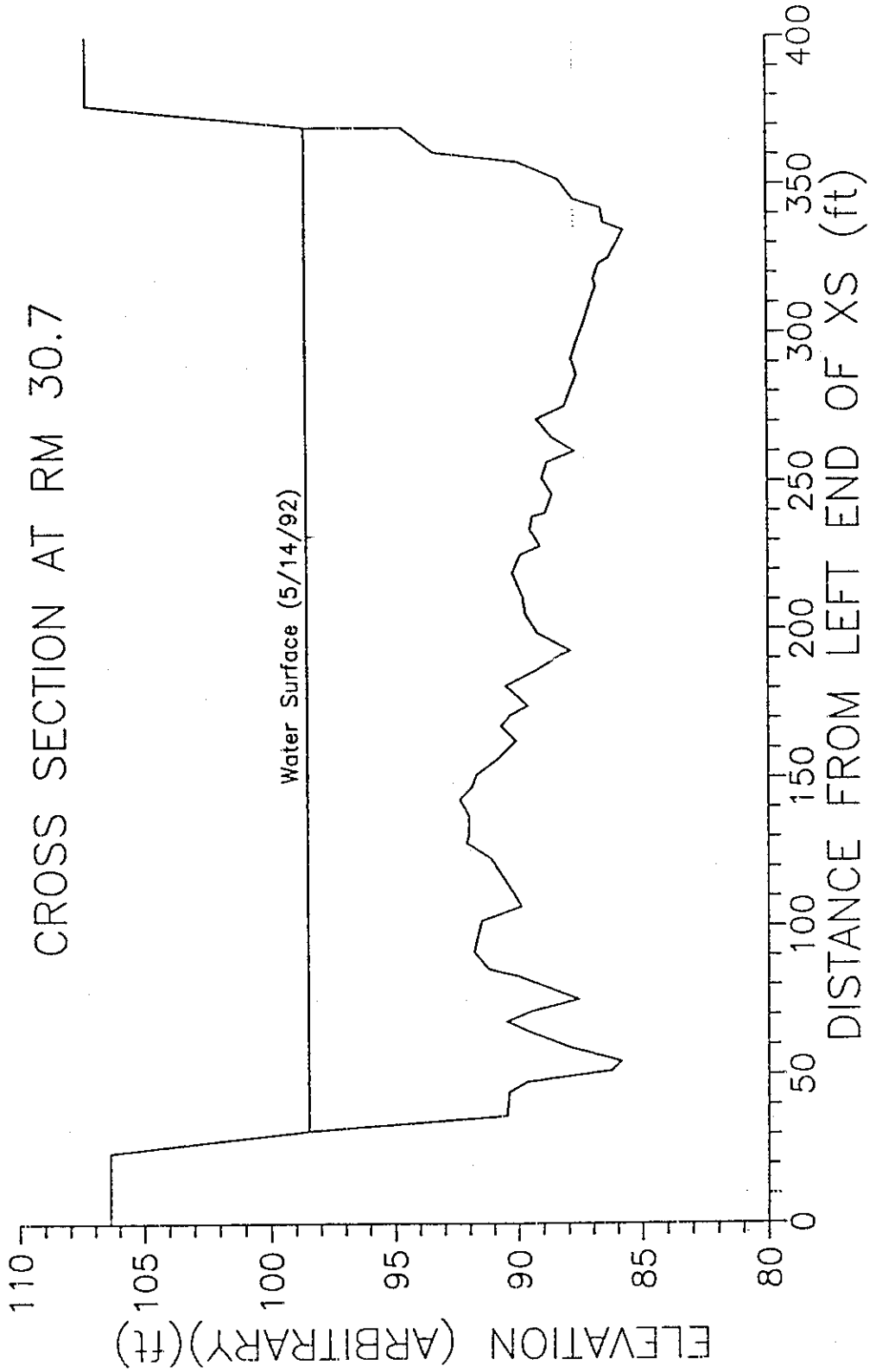
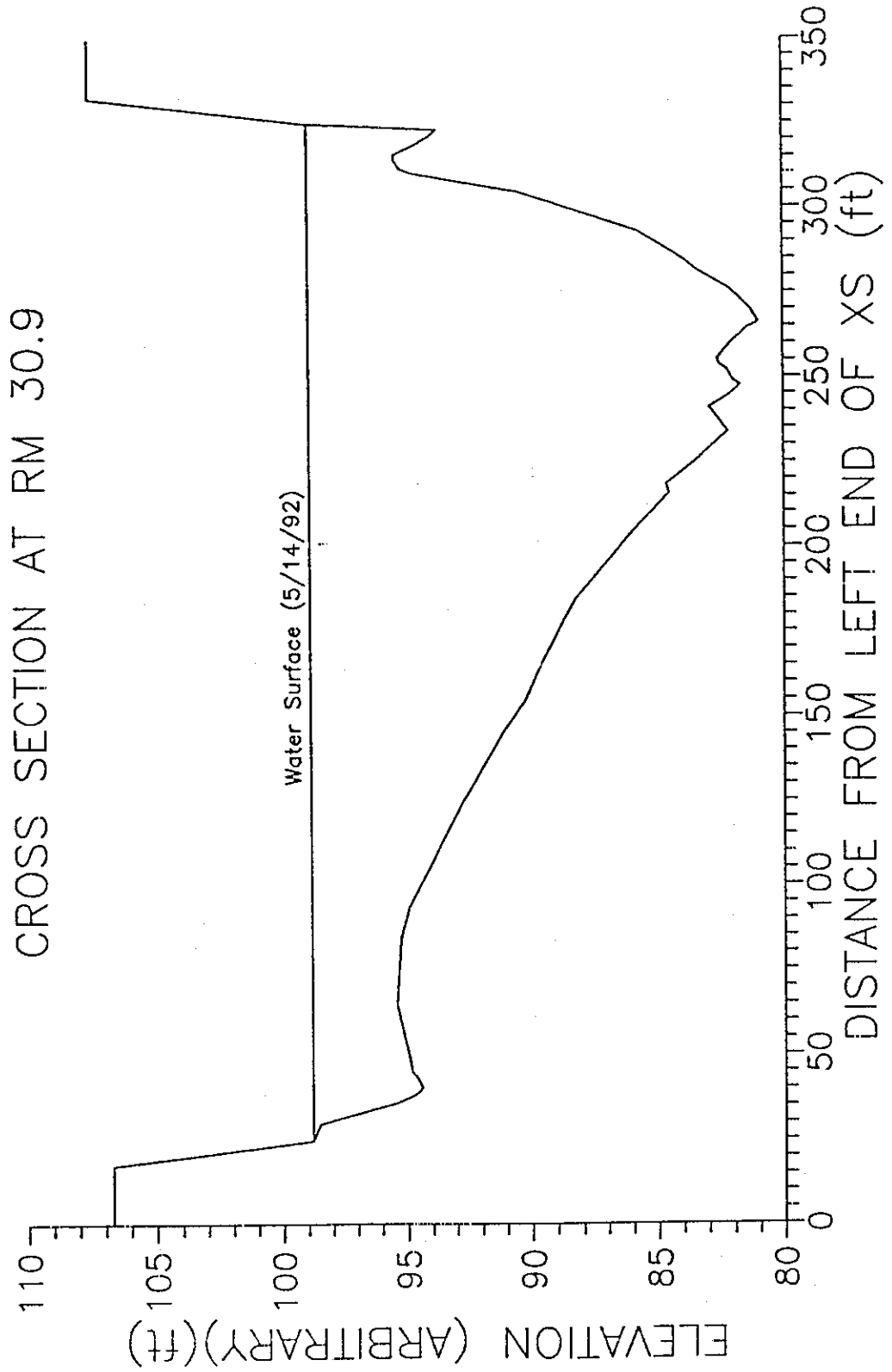
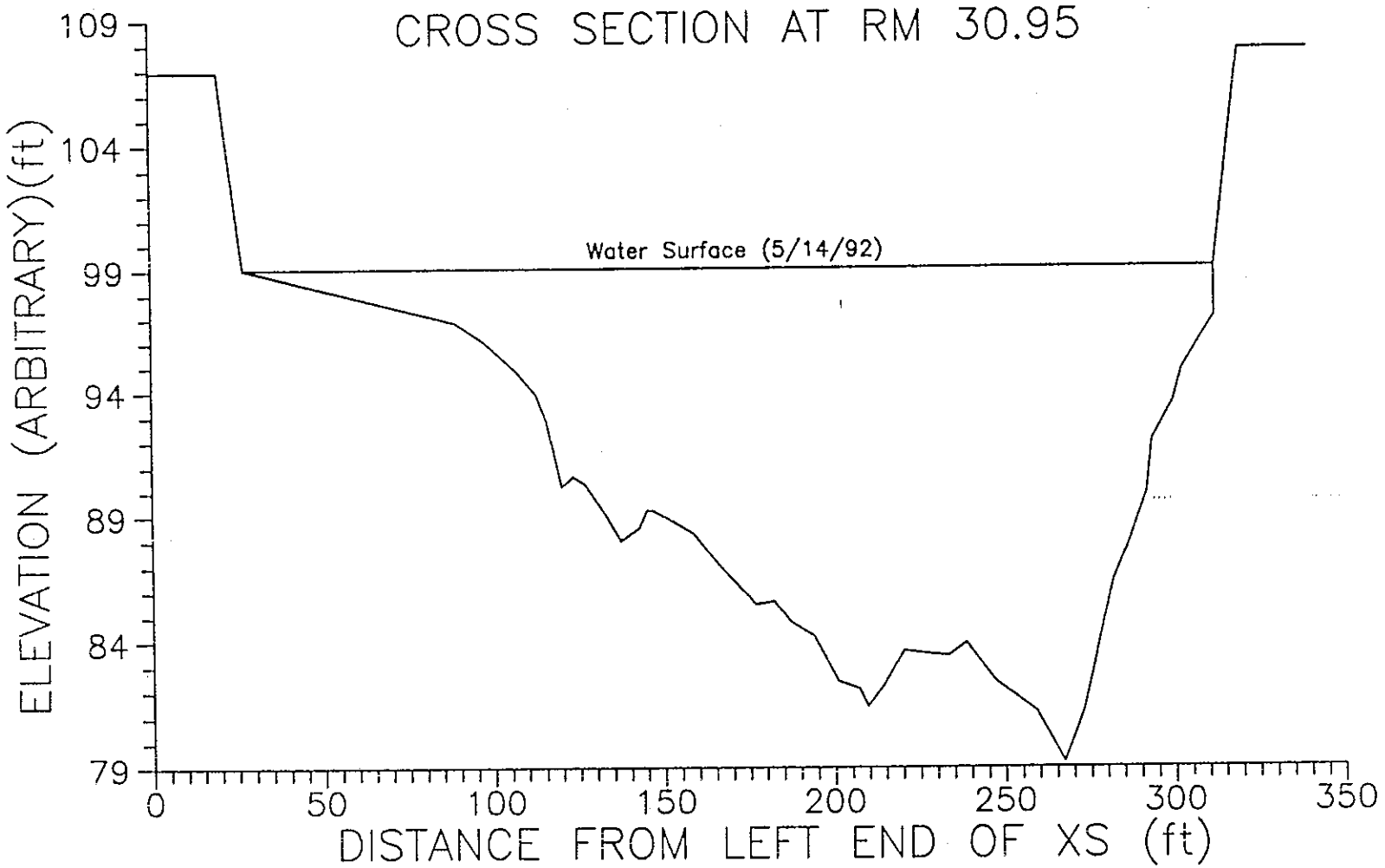

CROSS SECTION AT RM 30.7
Water Surface (5/14/92)
ELEVATION (ARBITRARY)(ft)
110
105
100
95
90
85
80
0
50
100
150
200
250
300
350
400
DISTANCE FROM LEFT END OF XS (ft)


CROSS SECTION AT RM 30.9
Water Surface (5/14/92)
ELEVATION (ARBITRARY)(ft)
110
105
100
95
90
85
80
0
50
100
150
200
250
300
350
DISTANCE FROM LEFT END OF XS (ft)



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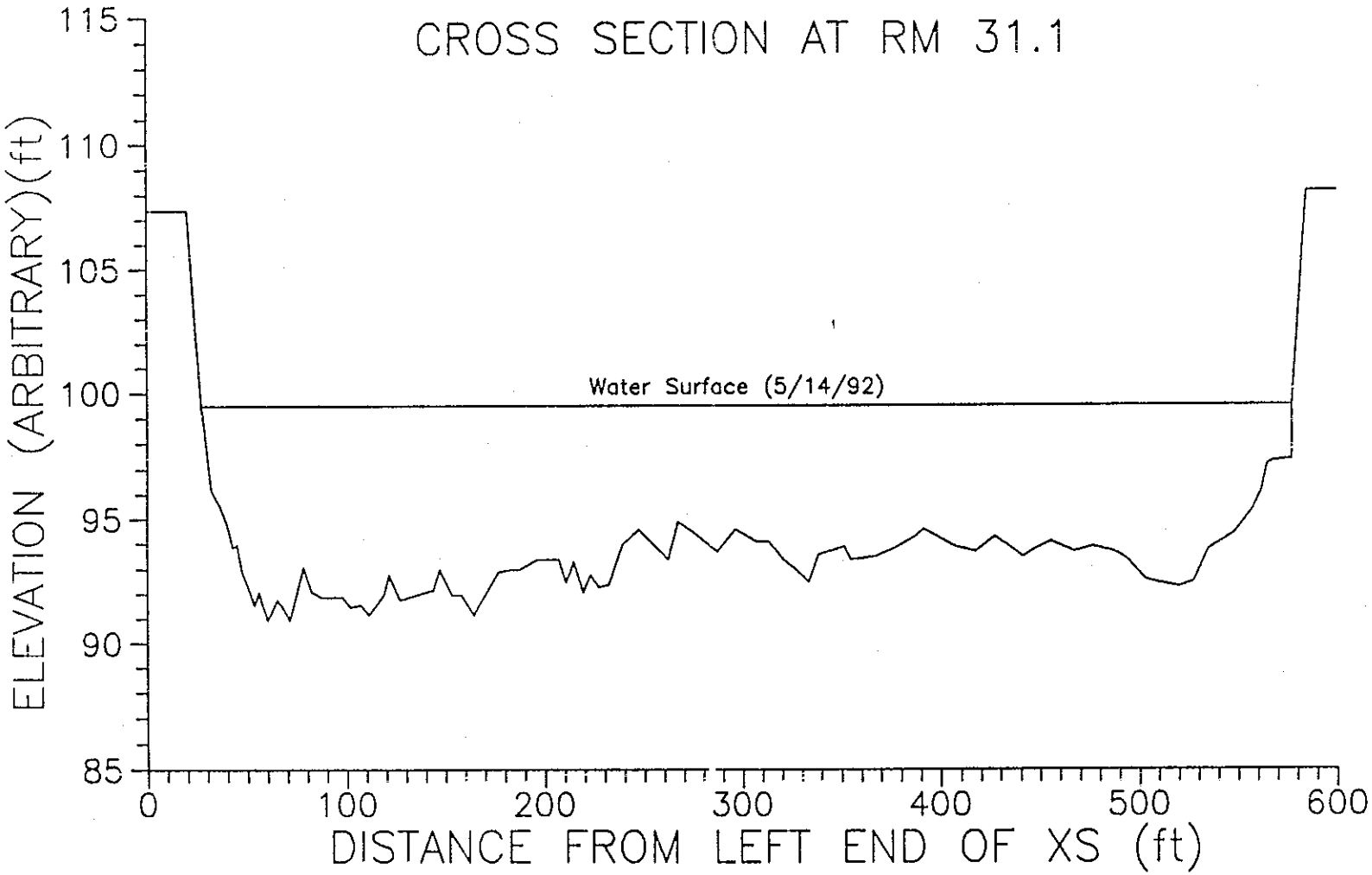

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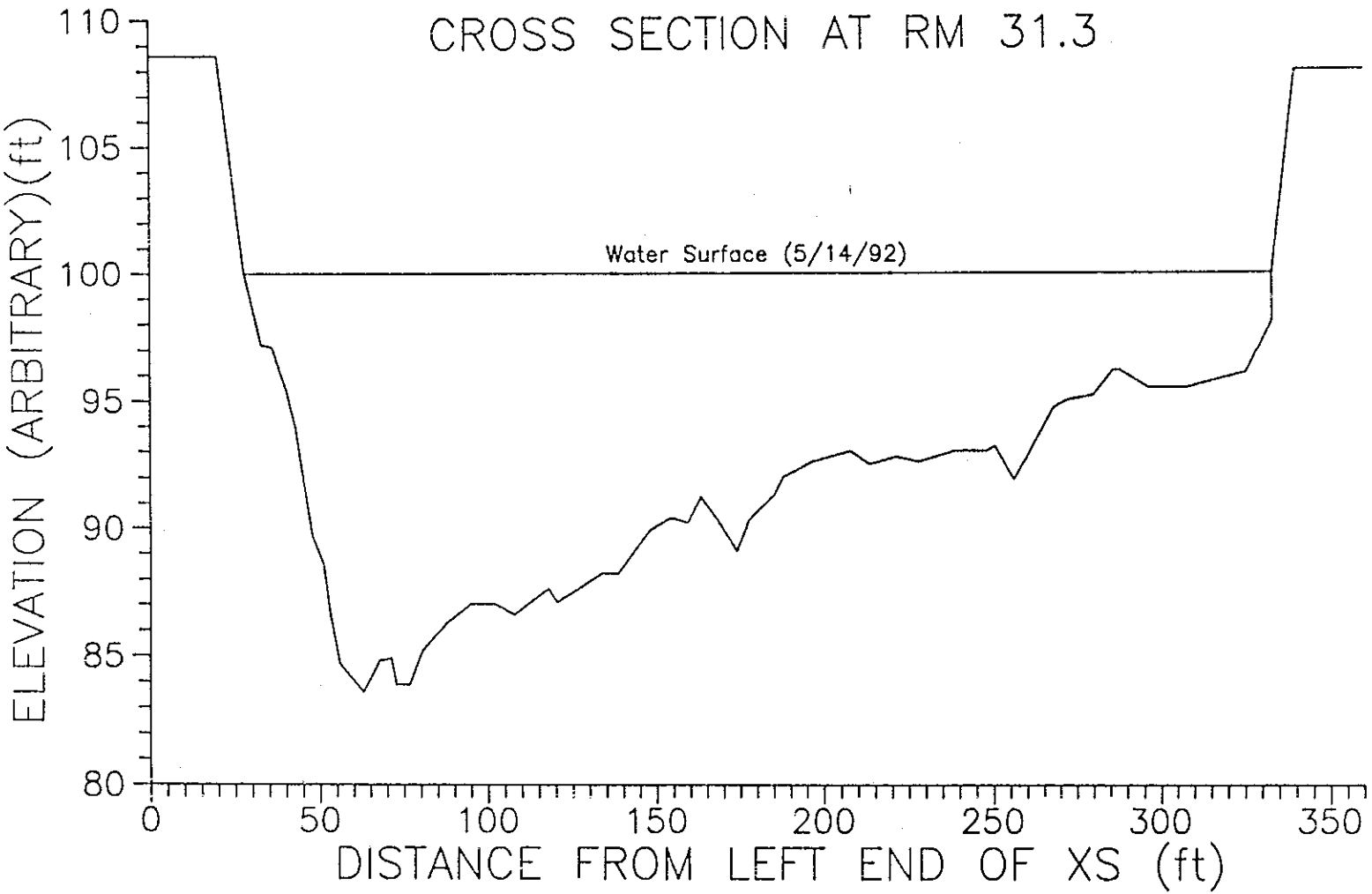

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